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TWELFTH UNITED NATIONS REGIONAL
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ASIA AND THE PACIFIC
Bangkok, 20-28 February 1991
Items 7 and 8 of the
provisional agenda*

CARTOGRAPHIC DATA RETRIEVAL, ANALYSIS, DEPICTION, PRESENTATION AND PRODUCT GENERATION

MANAGEMENT OF NATIONAL MAPPING AND CHARTING PROGRAMMES

Report on the Workshop on Training and Transfer of Technology in Digital Cartographic Data and Evaluation of Systems for Digital Mapping

Paper submitted by the United Nations Secretariat

During the Eleventh United Nations Regional Cartographic Conference for Asia and the Pacific in January 1987, a total of 23 resolutions were adopted several of which requested implementation by the United Nations.

In implementing resolutions 11, 13, 17 and 20 a Workshop on Training and Transfer of Technology in Digital Cartographic Systems for Digital Mapping was convened at the United Nations Office in Vienna, Austria, from 24 September to 2 October 1990 to study the situation and to make appropriate recommendations.

The Group** assembled at the Vienna International Centre on Monday, 24 September 1990 and began with a review of its terms of reference and objectives under the guidance of the elected Chairman, Prof. Fraser Taylor. After preliminary discussions, Prof. John McLaughlin presented his paper on "Trends and Issues in LIS/GIS" (Land Information Systems/Geographical Information Systems). As there was

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* E/CONF.83/1.

** List of workshop participants is shown in Annex 1.

some overlap with the points that Dr. Joel Morrison had made in his draft on "Computer Based Systems of Utility to Cartography 1990", Dr. Morrison then presented his paper. Both authors addressed issues related to technology, institutional and managerial arrangements.

With respect to resolutions 11 and 17 it was agreed to explore the distinction between record management and information management. The Group referred to the fact that there is much to be gained from improving the management of existing data sets that are often held in paper form, since it is common to find duplication of effort and activity between different organizations. The structuring of these data in support of decision-making and the treatment of data as a corporate resource pose separate problems and opportunities.

The target audience for the report to be prepared by the Group was discussed. It was recognized that for the purpose of the technical report, that to distinguish between developed and developing countries in the context of GIS was not appropriate because the distinction is primarily related to the extent of the availability of resources, rather than to any inherent differences in the types of technical and institutional problems that are faced. It was of course recognized that these problems differ considerably in intensity. The Group concluded that the prime target of the report would be the public sector and government agencies that would be attending the 12th United Nations Regional Cartographic Conference for Asia and the Pacific in Bangkok in February 1991.

The Group then addressed issues relating to data exchange standards. Prof. Brandenberger gave an overview of his perspective of the problems and recommended that an inventory be prepared of existing cartographic data bases and that a special working party be set up by the United Nations to develop international standards for data exchange. After consideration of the main issues involved it was felt that the rapidly changing form and content of data bases together with the complexity of the data layers which are involved made an inventory approach inappropriate. Unlike paper maps that are produced on a sheet by sheet basis, digital data are being compiled in different feature layers covering widely different areas. For instance, some countries are digitizing the road network or the hydrology without the underlying topographic data. Inventories would inevitably be incomplete, would be impossible to keep up-to-date and hence would be difficult to interpret.

The question of a working party on digital cartographic data exchange was discussed but it was noted that a very substantial amount of work had already been undertaken in this area, especially by the International Cartographic Association (ICA) with its own working group under the chairmanship of Dr. Harold Moellering. A report listing existing standards and discussing relevant issues had already been prepared by this group which met the content of resolution 13. It was proposed that Prof. Taylor as President of ICA should prepare a short introduction to this report and that UN/DTCD, as the organizer of the upcoming Conference in Bangkok, should invite a speaker from ICA to present the report and discuss its implications. The text of the response to resolution 13 is given in E/CONF.83/BP.3.

The establishment of a new working party was considered unnecessary since international standards are already emerging and will, to a large extent, be guided by market forces and commercial developments in communications technology and information transfer. Based on the deliberations, the Group structured the items to be included in an integrated report in response to resolutions 11 and 17 while resolution 20 has been addressed separately (see E/CONF.83/BP.4).

The report dealing with the implementation of resolutions 11 and 17 as derived during the sessions of the Working Group is contained in E/CONF.83/BP.2.

READEX FICHE

ANNEX

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TWELFTH UNITED NATIONS REGIONAL CARTOGRAPHIC
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Bangkok, 20-28 February 1991
Item 7 (b) (c) (d) of the provisional agenda*

CARTOGRAPHIC DATA RETRIEVAL, ANALYSIS, DEPICTION, PRESENTATION AND PRODUCT GENERATION: DIGITAL DATA BASES; LAND INFORMATION SYSTEMS; GEOGRAPHICAL INFORMATION SYSTEMS

Spatial information management in cartography

Paper submitted by the United Nations Secretariat

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INTRODUCTION

The report was prepared by a Working Group convened in Vienna from 24 September to 2 October 1990 by the United Nations Natural Resources and Energy Division/Department of Technical Co-operation for Development. The Workshop on Training and Transfer of Technology in Digital Cartographic Data and Evolution of Systems for Digital Mapping was held at the Vienna International Centre and was attended by experts in the field selected by the United Nations from nominations made by the International Cartographic Association (ICA), the Fédération Internationale de Geomètres (FIG) and the International Society for Photogrammetry and Remote Sensing (ISPRS), the current constituent members of the International Union for Surveys and Mapping (IUSM).

The objective of the Workshop was to implement several of the resolutions adopted during the eleventh United Nations Regional Cartographic Conference for Asia and the Pacific and to prepare documentation for the twelfth United Nations Regional Cartographic Conference to be held from 20 to 28 February 1991 at Bangkok. This document is in response to resolution 11 on Land Information and Geographical Information Systems (LIS/GIS) and resolution 17 on Evaluation of Systems for Digital Mapping. Resolution 11 recommends (a) the preparation of an in-depth study on the principal features and the different variations in the use, design, implementation and management of land information and geographical information systems; and (b) that information should be gathered on the various hardware available and that this information be communicated in a standard format to interested parties. Resolution 17 recommends that the United Nations should take note of the evaluations being made in scientific professional societies in the field of cartography and support, on the basis of this, an evaluation of existing systems and make this evaluation available to member countries."

Modern cartography is evolving very rapidly as a result of the information revolution driven by advances in computer and telecommunication technologies. The half life of knowledge in the computer field has shortened dramatically and new technological developments appear almost every month. The changes which have taken place since the eleventh Regional Cartographic Conference have meant that some aspects of the resolutions have become obsolete due to rapidly changing circumstances. Any summary of developments in hardware or of LIS/GIS capabilities will be out of date as soon as written, given the dynamic nature of the field. The structure and content of this report reflects this situation. An attempt has been made to meet requests in resolutions 11 and 17 and to provide documentation to Member States participating in the 12th Regional Cartographic Conference for the Pacific. This will be especially useful to the Member States for enhancing technology transfer and for preparing them for the challenges facing cartography as it moves into the twenty-first century.

The title for this paper "Spatial information management in cartography" was chosen carefully after considerable debate. There are numerous terms being used in current literature and in professional practice including GIS, LIS, Digital mapping, Computer aided Design/Computer aided Manufacture (CAD/CAM), Automated

Mapping/Facilities Management (AM/FM), Computer assisted Cartography and in many cases there is considerable confusion and debate over terminology and definition. The Working Group decided not to contribute to the definitional debate but chose instead a title which draws attention to a trend which will become increasingly important to national mapping agencies and all others involved in the mapping sciences. Cartographers are no longer only map producers; they are mapping complex spatial information using advanced and sophisticated technologies. The information revolution and its related technologies are giving new impetus to cartography and it is to these challenges that this report attempts to address itself.

The report is organized in three sections. The first deals with the prerequisites for spatial information management in cartography, the second with the basics of technology and the third with the selected trends and issues required and available to those involved or interested in the field. A report of this nature cannot be totally comprehensive but the Workshop concentrated on those issues of greatest relevance and interest to participants in the twelfth United Nations Regional Cartographic Conference for Asia and the Pacific.

I. PREREQUISITES FOR SPATIAL INFORMATION MANAGEMENT

A number of issues must be addressed before investing in spatial information management systems. There is a great range and diversity of applications and implementations that exist between countries and within any one country - from large centralized systems operated by central or local government (such as the Bangkok Land information System (BLIS)) to small implementations of limited extent in individual offices and independent organizations. It is important to consider and accommodate this diversity of systems within the national strategy. It is also important to establish what systems currently exist within a country, and what data sets are already available, before embarking on any new spatial information management project.

In the longer term, national policies must emerge for the management of spatially related data and these must integrate with governmental policies for the handling of information in general. If information is to be treated as a corporate resource and shared between different organizations, or within a single organization, then issues relating to the access and sharing of data must be addressed. The more open access that there is to the data, the more the system will be used and the greater will be its value. Policies need to be developed, among others on copyright, pricing, legal liability for data, confidentiality and security. Without open access to much of the data, the full benefits of spatial information systems cannot be gained. There needs to be an overall national strategy for data integration.

A corollary to accessing data sets is the need to develop national standards for the transfer and exchange of data. In addition to exchange formats there must be standards related to data quality, data definitions and classifications, data coding and spatial referencing. Progress towards data conversion and the establishment of local spatial information systems can proceed without a national geodetic framework provided that the system is designed to incorporate future

integration. Improved record management can take place without the data being initially connected to the national survey grid provided that compatibility exists at the local level, for instance through the use of a common land parcel identifier system. To make full use of the spatial analysis techniques that are often provided in spatial information management systems, an integrated spatial framework must be developed if it is not already available.

Many systems have in the past been developed on a "producer driven" basis without a clear knowledge and understanding of the needs of potential users. Systems are unlikely to be cost-effective until they contain a critical mass of information at which point there can be an explosive demand for the data. Below such critical volume of data within the system, the demand from users can be small or even non-existent. User analysis studies are essential to determine user requirements. These should be preceded by user awareness presentations so that potential users can understand the opportunities offered by the new technologies. Such awareness presentations should avoid the over-statement that has been all too common in the past and should lay emphasis on the cost of data. This may equate with some 70 per cent of the up-front costs in setting up a system. The cost of Geographical Information System (GIS) hardware and software is only a small percentage of the overall costs of setting up a system; the data are often the most expensive component.

In addition to the initial cost for procurement, there are continuous maintenance costs of the hardware and software, replacement costs of systems over time as they become obsolete, as well as the ongoing costs of updating the information that they contain, since systems must be treated as dynamic, incorporating change over time and responding flexibility to user needs. The costs of systems and data maintenance must be built into budgetary planning and strategies must be developed to ensure continuing financial support, for example from government sources, funding agencies or from other sources.

A further prerequisite in the acquisition and implementation of a spatial information management system is managerial and technical skills. Skills are required at all levels from data acquisition through data administration to overall management. These skills must both be acquired and continuously updated. Hands-on training of operators is important but on its own it is insufficient to ensure the success of any implementation. The single most important factor in the success or failure of systems implementation is often the lack of trained managers with appropriate skills and the inability of managers to ensure that problems are overcome and that continuing support is provided at all levels.

II. BASICS OF TECHNOLOGY

Cartographers are no longer only map producers, they are managers of complex spatial information and are required to utilize advanced and sophisticated technology. The production of maps and even the definition of a map has changed. A system for managing spatial information is composed of several stages with sets of processes that occur at each stage. Three static states are recognized and five dynamic functional sets of processes are identified. The static states consist of

data to be input into the system, data which have been converted to digital form and are resident in storage within the system and the final cartographic product. In between these static forms are five sets of functional processes which are to convert data to digits, to manipulate, to manage, to analyse, and to display data. A number of general texts provide an overview of systems for spatial information management (Aronoff, 1989; Burrough, 1986; Rhind and Mounsey 1990; Star and Estes, 1989; Taylor, 1990 and Tomlin, 1990).

To maintain and to operate a spatial information management system five components are necessary: human resources, data, software, hardware, and procedures. This section will not discuss the human resources although they are a necessary and vital component of the system. The discussion here will concentrate on the data that constitute the raw material of the system; software, that is, a set of instructions that the machine can understand and process; and hardware, that is, the physical machines that make up the system.

4.1 Data

Cartographers must manage and handle both data in their raw form and information derived from them. Spatial data must be converted into digital form, manipulated and managed, as must the analyses and display that transform data into information. Data are the most expensive component of a spatial information management system. They are also potentially the most long-lived. Good spatial data should never be discarded. At worst they should be stored in an archive. Unfortunately, the word archive has two meanings in cartography today. The traditional meaning is to refer to the storage of data for posterity on some time-tested medium. One contemporary use of archive is to denote the current holdings in a cartographic data base. In this paper the traditional meaning is used.

There are basically two ways to organize spatial data; raster form and vector form. Raster data are composed of pixels. A pixel is the smallest discrete element which makes up an image. A raster is a pattern of horizontal, parallel scan lines comprising an image, in which each scan line consists of segments varying in intensity. The term is now also used to refer to spatial data that consist of a matrix of values. Thus the category of raster data includes the matrix of intensity values for a series of uniform small areas (pixels) which when plotted in position create an image. Vector data on the other hand comprise directed line segments, with the magnitude and direction of each segment commonly represented by the co-ordinates of its end points. Vector and raster data are fundamentally different and must be treated differently. Manipulation and analysis processes exist for both types of data, and ideally the user should not be concerned whether data are stored as rasters or vectors. Conversion and display processes are readily available for both raster and vector data, and conversion from raster to vector and vector to raster is common. For a detailed discussion of the raster vs. vector issue see, for example, Burrough, 1986, or Star and Estes, 1990.

Today one common sequence of processes is to scan-digitize an existing map, edit the results in raster data, determine the centre lines of images and then convert these to vector form, adding the appropriate attributes. Much data listing in raster format, however, are never converted to vectors. Data received from

satellites are often kept in raster format. Examples of raster data include those derived from LANDSAT, AVHRR, SPOT, and from various other platforms in space. These are available and of potential for cartographic use. However, substantial preprocessing (geocoding, classification, etc.) may be required before such data bases may be incorporated as layers in a cartographic system. All aerial photographs and other space photographs, for available KFA-1000, can be scanned into raster format through the use of a scanner once the film is returned to the earth. The amount of these available data is extremely large. The utility of the data is more problematic since processing the data into an efficiently usable form may prove different. Plans for the future capture of even more data by several proposed satellite platforms assures that an enormous amount of data will be available in the future. These systems will give rise to significant telecommunication problems, data storage problems, and data management problems.

Raster data do not normally have associated attributes except for a nominal or intensity value; vector data often carry attributes. An attribute is simply a characteristic of a feature. With vector data, each vector may have one or more attributes connected to it and these are carried in the file along with the positional information. The distinction between geographic and cartographic data is another major difference. Cartographic data are those that are captured from a listing map either in raster or vector format. They may have been displaced from their correct positions in order to make the resulting map more legible. Thus, the spatial location of features may be intentionally displaced. On the other hand raster data from a satellite image or from a scanned aerial photograph are geographic data. These data after correction for the sensor and terrain differences are in their correct positions. The term geographic data is used to denote data which have positionally correct co-ordinates. In most mapping agencies the cartographer's ultimate goal is to have the entire data base as geographic data. Distortions to geographic data may however be necessary to aid the perception of the information during visualization or display.

Data entry requires trained personnel, expensive scanning or digitizing equipment, software to create the topological structure and templates to add the attributes and attribute values for a feature based data set. Data must also be edited and quality checked and these activities contribute to make data the most expansive component in the system - currently about 70 per cent of costs in a system are directly related to data.

Data must be organized in some form of structure or format. A data file has some logical order or sequence of fields that contain the digits that are in the file. The manipulation of these digits creates useful information. Within vector data at least three generations of vector files can be described. The first vector files are now called "spaghetti" data. Spaghetti data are simply unattributed strings of x,y co-ordinates - by plotting the series of strings, a map can be produced. However, limited capabilities exist to manipulate spaghetti data (mainly scalar changes) and few analytical capabilities can be performed on spaghetti data (point counts, line lengths, etc.).

The second generation of spatial vector data is now most common. This is referred to as topologically structured data and may be two dimensional (x,y plus attributes) data or three dimensional (x,y,z plus attributes) data. With

topologically structured data most manipulation and analytical processes can be performed. Topological structuring of data is a process of organizing data so that topological relationships and reference linkages are specified. Topological relationships refer to how data elements relate to each other within the data set. Data are often referred to as points or nodes, line segments or links, and areas or polygons. The topological relationships such as intersection and adjacency are defined by the attributes which accompany the points, lines or polygons.

The third generation of spatial data is feature-based topologically structured spatial data. Real world instances of entities are encoded along with attributes and attribute values for the attributes. More recent approaches store information on the types of operations that are or can be performed on spatial objects. This enables users, for example, to access all bridges over 100 metres in length and made of concrete, or all rivers over 20 metres wide and perennially flowing. If place names are encoded as attributes it will be possible to access the feature data by name, for example, Highway 4 between city x and city y. This type of data is far more "friendly" to all classes of users. It does not presuppose the attribute that any given user may wish to access. It should be noted that these data are also topologically structured. This enables all the manipulation and analytical processes to be performed in a more user friendly environment.

Additional data structures exist. Quadtree data structures, which hierarchically subdivide space along orthogonal directions, are sometimes useful in cartography. They have been used with raster data as well as with vector data. As vector data have become more sophisticated so too have the structures that hold them. Data that have many attributes not only require more editing, thus adding to the cost, but may also need more comply data structures. Further reading on data structures and data models include Dueker, 1987; Peuquet, 1984; and Burrough, 1986.

One unique category of data, the digital elevation model (DEM), is used extensively in cartography (Mark, 1978). One form of DEM is a matrix of elevation values usually spaced in an orderly fashion over an area of interest. Positions within the matrix when coupled with the applicable projectional and scalar constants define positions for the values in the world. DEMs have proven to be useful for a variety of tasks. Both analytical functions and visualization methods utilize DEMs to enable the user to obtain and understand data sets. Other DEM structures such as the Triangular Irregular Networks (TIN) are being increasingly used in cartography.

As cartographers become more experienced in their handling of spatial data, additional requirements are added and these data tend to become more complex in structure and attributes. Sophisticated index structures may be necessary to support fast data access or to aid complex operations. The net effect is that spatial data sets are becoming larger. Fortunately, the trends in hardware capacity and speed are moving faster than the data bases are increasing in size, so the capacity to operate with larger data bases exists. This increases the need for spatial data base management systems for the handling of cartographic data. It has become clear that standard DataBase Management Systems (DBMS) cannot fulfil all the functions required. As the volumes of digital data increase, the problems of managing the data increase as well. It is important to know where data are and that these data can be efficiently retrieved. Indexes of data coverage are

worthwhile products. The efficient partitioning and panelling of data are also necessary (see Armstrong and Densham, 1990). In a spatial context the need to store data in discrete sets, often called tiles, works against the user's desire to be able to move across an area as if it were seamless. A good DBMS can allow the digital data to appear seamless to the user.

4.2 Software

Software is the set of instructions which are written to tell a machine what operation to perform in what sequence. In support of the broad range of processes for spatial data handling, instruction sets are organized into functional modules, software packages and integrated systems for cartographic data processing. Areas of small concern are the language in which a given set of instructions is encoded. The functionality contained in the instructions, the transportability of the software from one system to another and the "user friendliness" of the software.

The programming language used for a set of software instructions may vary and the exact language is of less importance to the cartographer than it once was. To be able to add to or modify a given software package may require a knowledgeable individual who can program in the language in which the software is written. Two conditions occur however: often vendors are reluctant to release their code to enable others to write additional lines to it; and, increasingly, cartographers are depending upon computer scientists to write the additional lines of code since languages are becoming more complex and as instruction sets are becoming more complicated. A cartographer working with a computer scientist and others as a team is proving very valuable in writing necessary instructions.

Functionality varies tremendously from system to system yet ideally many of the functions discussed below should be available in all the software systems that a cartographer needs (Dangermond, 1987; Goodchild, 1988a and 1988b). Some of the common categories of functionality are measurement, generation of buffers, map algebra functions, polygon operations, terrain analysis (using DEMs) and others. The measurement processes include the ability to measure both straight line and curved distances, proximity distance and area. The generation of buffers allows the cartographer to generate zones around points, lines, or polygons for use in analysis. Map algebra functions include the ability to add/subtract or multiply/divide maps, and to employ trigonometric functions or differentiate values. Polygon operations include polygon overlay, point or line in polygon determination, merge/dissolve, delete spurious polygon overlays, and to create Thiessen polygons.

Terrain analysis using DEMs is a separate class of functionality (Raper, 1989). At each entry in the matrix of a regular grid DEM is the value above some defined datum for some distribution. Analysis of DEM data then consists of, for example, the computation of slope, aspect, or intervisibility. The creation of contours, or the interpolation of a denser matrix of elevational data values can also be undertaken. Drainage networks, cross sections and cut and fill calculations can also be accomplished by using DEM data in a regular matrix. DEM data are proving useful in visualization as well.

More specialized functionality includes the ability to perform analyses within corridors, to do nearest neighbour searches, to compute optimal paths and to perform network analyses. Vector to raster and raster to vector conversion is also available in some software packages.

Software is also needed for visualization. Both output displays and image processing techniques are useful and readily available. Several routines for output that are in common use with spatial data are the ability to create three dimensional shaded relief, three dimensional wireframe diagrams, or three dimensional thematic layers. These give the appearance or impression of three dimensions on a two dimensional screen. Perspective plots are also useful tools for visualization, as are raster and vector maps. There are several tools that are very useful to use in conjunction with these display software options. These tools include the ability to georeference a spatial display, spatial reference determination by touch screen or cursor, or the ability to input a spatial reference by cursor, co-crdinate value or mouse; The capability to pan and zoom on a display is also widely available and useful for cartographers.

A separate set of software routines provides the cartographer with raster processing techniques (Star and Estes, 1989). Some software packages exist only for work with image processing using data in raster formats. Such packages include the abilities to classify images, to density stretch or slice, rectify images and/or orthogonalize the image. Increasingly cartographers want to use a rectified or an ortho-rectified image as a backdrop for the processing of vector information. Many opportunities to do this are presently becoming available. This capability will be of great utility in the updating and revision of cartographic data. New imagery will be obtained and that operator will be able to bring the vector file resident in the data base onto the screen and register it to the newly obtained ortho-rectified image. Changes should be readily apparent and the operator will be able to update the existing vector file to reflect the noted changes.

Besides the software necessary to perform the specific spatial data processing, a wide range of utility software may be necessary for efficient cartographic data management. These utility software routines include functions such as user interface features for spatial data, basic graphics software, statistical packages etc.

Another desirable characteristic of software is its transportability. This issue depends on both the hardware and the software. Some software packages are available in different versions depending on the specific hardware configuration. Some software packages are not supported on some hardware platforms. As cartographers move to "open" system architectures some of the problems that arise due to incompatible systems may vanish as systems operating only on one hardware platform can be accessed from another hardware terminal. Cartographers are not yet in the age of "open" system architecture but it will be available to most users soon.

Because data are so expensive to create and to maintain, the ability to access existing data that resides in common formats is very important. Data conversion software exists. A number of common formats are in use today (ARC, DEM, DIME, DLG,

DTED, DXF, ELAS, EPSF, ERDAS, GIBAS, HPGL, IGES, ISIF, LANDSAT, MOSS, NTF, SIF, SPOT, TIGER etc.). Software packages that allow access to data in a great number of these formats are therefore of greater utility to the user than packages that are limited to few formats. The lack of standards for data exchange is one reason that has enabled these various formats to come into existence and has complicated the data transfer process. Several groups are working on exchange formats that will enable a standardized exchange among the spatial data in existence. These standards will greatly facilitate the exchange of digital spatial data among users and should reduce the overall cost of operations for most digital cartographic users.

Software comes in varying degrees of "user friendliness". It is not surprising that complex software packages tend to be less user friendly. Yet for a given level of complexity some software packages are easier to learn and use. Standard training courses are available for some complex software packages, while others include tutorials along with the software to enable self training. Regardless of the amount of formal training or self training it remains a fact that one must constantly use a software package to become proficient. Often to increase the user friendliness of a software package it is merely a matter of adding comments to the software that tell the user what is happening or what has gone wrong. The use of easy to understand menus also can greatly add to the user friendliness of a software package.

Spatial data handling software is available in a wide variety of forms, ranging in price from the cost of reproduction and handling to packages with price tags of tens of thousands of dollars for a single licence at an installation. The selection and installation of software for spatial information management is a complex process in which factors such as data format, speed of processing and other considerations as well as cost must be taken into account (Dickinson and Calkins, 1988; GIS World, 1990; Guptill, 1988).

At the present time the development and creation of software is more costly than the purchase of hardware. Costs for the development of software may be three to five times the costs of procuring the hardware. Whenever possible existing software packages should be investigated to see if they contain the functionality required for a given operation. Several software packages are now on the market that provide most of the functions that are routinely needed by cartographers.

4.3 Hardware

In discussing hardware, it is important to differentiate between processing devices and peripherals. Processing devices are computers and primarily perform operations or direct peripheral devices to perform operations. Peripheral devices on the other hand may only do one function. As the computer industry matures, peripheral devices are becoming more intelligent and many in fact today contain small processing units. For the purposes of this discussion, however, processing devices will be separated from peripheral devices.

Processing device hardware is currently experiencing an 18-month life cycle. Vendors are releasing essentially a new generation of hardware processing devices every 18 months, which for the most part has double the capacity and twice the

speed of the previous generation equipment. It appears that this will continue for at least two or three more cycles and maybe longer. The effect of this is critical in today's market and may mislead first-time users, to whom the costs of hardware appear to be very expensive. This is especially true of the larger and more sophisticated workstations, which can exceed $100,000 in cost. With an 18-month cycle, this may mean that equipment purchased has been superseded by newer equipment even before it is installed and fully running. Furthermore, the newer generations of hardware often are less expensive than their predecessors.

Processing devices consist of micros (including personal computers), minis, mainframes, and supercomputers. As the generations of hardware pass, capabilities that were characteristic of mainframes in 1965 now reside on micros. Supercomputer capacity of yesterday will reside on your desktop tomorrow. Each processor has an operating system. Various operating systems are in common use today, for example, DOS and UNIX. Fortunately, hardware manufacturers are moving away from full reliance on one operating system and as we move to "open" system environments, the need for compatible operating systems may vanish. This also means that the idea of turnkey systems becomes obsolete. In an "open" system environment users may access various platforms for GIS software packages, and conversely various GIS software packages can operate on various platforms. The operating system will become transparent to the user.

Processing devices come with some storage capacity but in most instances cartographers need more storage for their very large spatial data files than a processor normally has. Traditionally cartographers have made use of magnetic tape or even paper tapes and much archival material is still held on magnetic tape. Punched cards may have been the first storage device for cartographic data, but today these are no longer suitable for spatial data management. Today's storage devices include CB-ROMs, optical disks and digital cassette recorders (DCR). CD-ROMs are compact disks that hold large amounts of data, for example several maps or many photographs, in digital form on one small disk. CD-ROMs are small, lightweight and nearly indestructible. Optical disks and DCRs hold vast quantities of data, for instance optical disks can hold several gigabytes of data. Both optical disks and DCRs can provide access within a second or so, to 50 disks or cassettes in "juke box" fashion. Some versions of optical disk are useful to physically transport large volumes of data.

Peripheral hardware devices are not developing at the same speed as processing devices. Nevertheless, tremendous strides have been made in the last few years especially in input devices, workstations and output devices. Small, easy-to-use devices such as the mouse, light pen and touch screen have been developed but these will not be discussed here.

Scanners and digitizer can range from a portable small-surface digitizer, costing several thousand dollars to large format, high precision scanners, costing nearly $1 million. This hardware is used to convert existing static state data, either maps or images, into digital data. Software is used to convert the machine dependent format data into the system format.

The price of digitizing equipment is a function of the precision and size of the table. Three-dimensional digitizing is possible when electronics are added to stereoplotting instruments to send the x,y,z co-ordinates to a data base. Scanners collect raster data either directly from airborne or spaceborne platforms or from documents that are mounted on a drum or flat surface. The speed and precision along with the acceptable format size are the major determinants of the cost of scanners. This data capture technique often relies on appropriate software to extract meaningful information on features from the raster matrices produced by the scanner.

Workstations are interactive terminals that allow an operator to manipulate digital spatial data; they can also, in some instances, serve as full processors. The terminals available today range from a personal computer to extremely sophisticated dual screened workstations that cost hundreds of thousands of dollars. Most workstations include a small to medium-sized processing device and are linked to other processing devices. These instruments allow the operator to retrieve data from another stage or state and manipulate or analyse those data and then to return them to another static storage state. The larger workstation may include a digitizing table, pre-printed menus and many visualization utility software routines in addition to its processor. The utility of a workstation is dependent upon its software functionality. As systems become more "open", workstations should be able to access software that is resident on other workstations that are connected to the same network.

Output devices include plotters and printers. The costs of these devices run from that of a portable vector plotter for a few thousand dollars to stable instruments that can plot or "write" ink to paper, scribe, or expose film with lasers and may cost nearly one million dollars. Some output devices are custom made to serve limited purposes. Others are widely available, for example laser printers or electrostatic plotters. These instruments are usually either drum or flatbed and can operate with either raster or vector data. Rarely will precision instruments plot both types of data.

To link processing devices with other processors or peripherals, communication hardware and software are necessary. This is an area of growing importance as cartographers move to more complex and larger systems which are networked. In the era of turnkey systems the linkage of devices was of minor concern. In the forthcoming era of distributive systems and "open" environments, the linkage of devices is paramount in importance. Fortunately, communication linkages in computer environments are important to all users of computers and, in this arena, developments are rapidly progressing. The cartographic needs and uses are but a small part of the demand for telecommunication hardware and software today. Local area networks (LANs) and wide area networks (WANs) are becoming commonplace. These will support open environments. Cartographers need very high transfer rates for data since, in general, their spatial data files are larger than most other computer files. The transportation of these large data files across communication lines must be done so as not to disrupt the operator at a workstation. At present, all of the needs of cartographers are not being met in this area of telecommunication.

The hardware environment for spatial data management, therefore, consists of a suite of linked processing devices, storage devices and peripherals. Software packages containing the functionality required for the performance of cartographic operations run on such equipment. The current environment is dynamic as the processing devices are changing very rapidly (Dangermond and Morehouse, 1987). Developments are still needed in the telecommunication area to aid in the efficient transporting and processing of digital spatial data. Developments in peripheral equipment have been the most responsive to cartography and the peripheral devices that cartographers need are generally available today.

III. TRENDS AND ISSUES

This section will deal with trends and issues in the field of spatial information management. It will briefly (a) review the evolving requirements for spatial information and look at procedures employed to define such requirements; (b) examine the technology trends in the field and review how decisions are made regarding the acquisition of appropriate tools; (c) examine systems development trends and especially the evolution from single-purpose project-oriented systems towards an integrated spatial information infrastructure; (d) discuss evolving standards for spatial information management; (e) review some of the major management issues associated with building spatial information systems and procuring the appropriate technology.

5.1 Evolving user requirements

In both developed and developing countries, the pressures on land and the need to strike a balance between the exploitation and conservation of land resources have lent a sense of urgency to resource management issues. In the developed world, the need to determine the effects of environmental pollutants like acid rain and toxic wastes on both people and the environment has gathered momentum once again. In less developed countries, the need to achieve a basic level of sustainable development has been the driving factor. In both cases, the need for timely, accurate and more meaningful information describing land and marine resources has been identified as a fundamental concern from environmental, economic and institutional perspectives.

Much of the interest and activity in the spatial information field has been driven by revolutionary changes in the tools for positioning and acquiring spatial data, for analysing and managing these data, and for integrating and disseminating the resulting information products. As a new generation of microcomputer-based mapping, spatial analysis and decision-support tools is coming to market, this interest is exploding. At the same time, however, it has been the less glamorous efforts of building and maintaining the necessary digital data bases which have consumed most of the available resources. Now moving into an increasingly data-rich environment, emphasis is shifting to the institutional arrangements necessary to underpin the information infrastructure and to support the wide range of potential applications of these data bases.

Spatial information in developing countries has been mainly acquired to support either basic administration or development (Furmston and Logan, 1986). Most of the information required for basic administration activities has been collected and maintained to support operational control for decisions related to, for example, land registration and property assessment. Information required for development activities may have to support operational, management and planning decisions, depending on the nature and stage of the development in question. For example, different types of highly aggregated resource information presented at a small scale may suffice for strategic planning of aquaculture development along a coastline, while detailed large scale information will be required for final highway construction.

These developments are being accompanied (and are increasingly being driven) by changes in user requirements. Some of the trends are:

(a) Changing requirements for spatially related information (increased focus on integrated resource development and management; renewed concern about the environment; recognized need to view development from environmental, economic and institutional perspectives);

(b) Growing awareness of the costs involved in gathering and managing spatial data bases, and a slowly emerging appreciation for the importance of treating information as a corporate resource;

(c) Growing sophistication of the user community (both in terms of technical literacy and in terms of the potential role of information in the decision-making process).

One final area to note is the growing interest in developing world data sets in support of such activities as environmental monitoring, global modelling and studying global change (Mounsey and Tomlinson, 1988).

One existing data set, the World Data Base II, is in widespread use and has been incorporated into some existing software packages. This data set, most of which was encoded at scales around 1:4,000,000, is out of date but is still the best available world-wide vector data base in 1990. Another data set is in the process of being developed, The Digital Chart of the World (DCW). When completed at the beginning of 1992, the DCW will reside on 29 CD-ROMs and will contain the information on the 1:1,000,000 Operational Navigation Charts of the World. This information will be the largest scaled consistently formatted data set of the world that cartographers will have available. The data will be of the same date as the printed maps series which is about 1980.

Various national data bases are now available or are in the process of being created. At some point in time these will be the equivalent in digital data bases of the current topographic map coverages of the countries of the world. In addition, as the international Geosphere and Biosphere Program becomes a reality, other large data sets of spatially referenced data will become available.

5.2 Defining user requirements

Currently at least three approaches are used to help define user needs and information requirements:

(a) The generic user needs approach;

(b) The mandate versus informatics requirements approach;

(c) The economic assessment approach.

After the geographical data requirements of many users, Dangermond and others (1983) concluded that the most effective short-term approach was to (a) define the generic tasks that the users in question perform, (b) identify the generic types of geographical data required for those tasks to occur and then (c) determine the generic types of reports and analyses required as a result of those tasks. Many of these requirements can then be matched with the specific capabilities of available technology. If such a study has not been carried out in an organization, this approach can provide invaluable insight into agency functions and information products. However, there is usually no mention made of what to do if specific geographical data are required but are not available (as is common in developing countries). Further, the approach does not necessarily consider inter-agency data flows nor explain why an agency stores and analyses information in the way it does. Such analyses of needs are usually initiated as a prelude to the system acquisition process and tend to focus on such issues as (a) the size of system required, (b) its configuration and (c) how it is to be integrated with other systems. While these are important questions, there is concern (particularly in developing countries) that the fundamental needs and working conditions may become of secondary importance.

In the mandate approach, the emphasis is not on the flow of the data, but rather on the types of information required to fulfil a given mandate. A mandate, which may be a law, an administrative rule or even simply a customary practice, provides the definitions of the objects of interest along with the procedures for processing information. In place of the user need approach, mandates provide a deeper view of why information is collected by certain agencies.

Under the mandate approach, the functional responsibilities and routine activities of the jurisdiction or agency are first defined in detail. Once this has been carried out, the present (and perhaps future) information requirements are reassessed in terms of data collected, ongoing data maintenance requirements and information flow (Chrisman, 1987, and Nichols, 1987).

In many cases a formal economic analysis may be prepared in conjunction with the user requirements determination. In municipalities and utilities, benefit/cost studies are now commonly carried out by consulting firms prior to the acquisition of GIS or AM/FM systems. On a broader scale, the application of economic analysis to spatial information systems and programmes has received increased attention in the research community (Blaine and others, 1987) and a growing collection of documented case studies is now appearing (Nordisk Kvantif, 1987, and Didier, 1990).

Organizations in developing countries often face special constraints in determining their own requirements. Today, even basic administration activities are falling behind because of constantly changing conditions in urban and rural areas. Information for development purposes (e.g., road construction, integrated rural development and electricity supply) tends to be gathered on a needs basis and rarely incorporated into an integrated spatial information system. Further, Drummond and Stefanovic (1986) point out that one of the continuing problems in technology transfer is that the respective motivations of technology recipients in developing countries and international suppliers may vary significantly. Solutions fashioned for use in Europe and North America often fail when faced with the constraints of climate, inadequate facilities, shortages of skilled manpower and cultural differences which influence the collection and management of spatial information in developing countries. Finally, Dunkerley (1986) notes that the vested interests of lawyers, surveyors and other professions in maintaining existing arrangements often cloud the identification of true requirements.

5.3 Technology trends

Recent years have seen dramatic changes in the spatial information technologies, especially with the introduction of increasingly powerful microcomputer-based tools for spatial analysis and information management.

The trend with respect to GIS technology is described in table 1. Here the hardware emphasis has gone from mainframes to minicomputers to microcomputers and now to multiple platforms in a networked milieu. During this same period, the software focus, which began with computer-assisted mapping and simple spatial query capabilities, has moved on to geographical analysis and to data base management problems and will increasingly be concerned with decision support and the broader management information systems (MIS) environment. Similar developments, some even more dramatic, can be sketched out for the other spatial information technologies (Global Positioning System (GPS), PC-based photogrammetric instrumentation, intelligent scanning etc.).

Kotef (1988) suggests that five technological trends will dominate the industry over the next few years:

(a) GIS Standards will play a major role in consumer decision-making and will represent a key area for strategic control of the market;

(b) Networks will continue to grow in size and number as greater vendor support is provided;

(c) Processing power will increase drastically through the introduction of such chips as the Intel 80486 and will process up to 1,000 maps (a million instructions per second) by the mid-1990s (Kotef, 1988). Dangermond (1988) suggests that some basic GIS operations (polygon overlay, for example) may be moved on to a chip by the early 1990s;

	1976	1981	1986	1991
SYSTEM ARCHITECTURE	MAIN - FRAME	16-BIT MINI	32-BIT MINI	MULTIPLE PLATFORMS
PROCESSING ENVIRONMENT	CENTRAL D/P DEPT.	DEDICATED PROCESSOR	PROFESS'N'L WORKSTN: SINGLE SYSTEM NETWORK	PERSONAL WORKSTN: MULTI SYSTEM NETWORK
PRIMARY EMPHASIS	MAP PRODUCTION	MAPPING AND ATTRIBUTE RETRIEVAL	GEOGRAPHIC MODELLING	DECISION SUPPORT
SOFTWARE COST	MAINLY NON-COMMERCIAL SOFTWARE	$100 TO $200 K	$100 TO $200 K	Under $10 K TO $200 K
HARDWARE COST (cpu, storage, input and output)	APPROX. $450 K FOR IBM 370 ALONE	APPROX. $150 - $300 K PDP-BASED SYSTEM	APPROX. $100 - $250 K VAX-BASED SYSTEM	$50 K AND LESS

Table 1. GEOGRAPHIC INFORMATION SYSTEMS TRENDS

/...

(d) Fully distributed applications will become possible once programming, product and information standards are in place, which will ensure portability and inter-operability among different systems;

(e) Fully distributed data base management will minimize - but probably not eliminate - the need for storing redundant "tombstone data" (i.e., basic ownership information), as well as updated map data, in many different systems in a jurisdiction. With such an infrastructure in place, map data base updating will be completed on an ongoing transactional basis, rather than through batch operations completed (at best) every 3 to 5 years.

Increasingly, attention is also shifting from turnkey geographic information systems to application-oriented software systems bundling together DBMS, GIS, MIS communication and application packages. Of particular interest in this regard is the potential application of decision support tools, such as expert systems. Generally speaking, expert systems are software programs that make use of a set of rules to provide advice on, or help solve, real world problems requiring an expert's interpretation. While not widely used in spatial management to date, expert systems are now being adapted in a research environment to problems in cartographic design, data base access, and terrain and feature extraction. In limited cases, expert system "shells" have been linked with geographical information systems to assist in site location and constraint mapping activities. Over the next 10 years, expert system shells will increasingly take advantage of the formalized knowledge and experience now being developed in spatial information management. In addition to current applications, these systems will be applied to the problem of distributed data base management access and control, reconciling different map overlays to the same spatial base and applying well-known but complex combinations of rules to problems in the management of scarce resources.

Finally, while the volume and variety of data being stored grow almost exponentially, developments in data management have become especially important to the spatial information field. While the output graphics and analysis functions still demand serious attention, users in major ongoing programmes now recognize that database organization, loading and maintenance will be a major determinant in the performance and long-term success of spatial information systems. As Lee and Zhang (1989) have noted, the management of spatial data poses some very special problems:

(a) The representation of spatial objects is generally longer, more complex and less standardized than is the case with conventional textual records;

(b) There does not yet exist a standard set of operators for manipulating spatial objects;

(c) Because of the geometrical complexity of the spatial objects, editing and processing the data take a relatively long time.

A number of experimental strategies have been developed to address these problems including the use of kernel data bases and object-oriented data bases, but their potential is only beginning to be realized in a commercial environment (Lee and Zhang, 1989).

5.4 System developments

In a number of jurisdictions, the first use of computers in surveying and mapping, the first efforts at automating land records and the first attempts to build urban and regional information systems date back nearly 30 years.

Over the last 15 years, billions of dollars have been invested in North America, Europe and elsewhere on constructing data bases in support of environmental monitoring and resource planning, land administration, facilities management, etc. For example, increasing pressures to more effectively manage scarce resources motivated several jurisdictions to enact legislation which implicitly encouraged the use of more sophisticated modelling tools for resource management. Across Canada, for example, federal-provincial forestry agreements demanded more detailed long-term planning for timber management. As a result, virtually every government forest management department in Canada (as well as almost every major forestry company) was compelled to consider the adoption of GIS technology in order to prepare these plans. In the United States, a series of mandated federal programmes for conservation planning, including the 1985 Federal Security Act, has played a significant role in promoting spatial information activities. For example, the U.S. Soil Conservation Service has undertaken major programmes at the county level to determine soil erosion susceptibility and to monitor the success of control efforts.

Concerns for protecting environmentally sensitive areas, such as wetlands and the habitats of endangered species, have resulted in the need to obtain an increasing number of permits - and hence in the need to collect an increasing amount of spatial information - before land can be developed or its use changed. GIS technology is becoming an accepted tool for managing the information collected for Environmental Impact Assessments and other mandated studies. GIS and digital mapping technology have also had an impact on many other areas. Most large public and private utilities have constructed or are actively considering the construction of AM/FM systems. Large cities in several countries have been automating their engineering, planning, emergency services and building records for more than a decade. More recently even smaller cities, with population as small as perhaps 50,000, have also begun to build integrated urban information systems.

Now the emphasis is beginning to shift towards the integration of these systems into some kind of a network environment. The notion of distributed spatial information network has been discussed for several years, and much pioneering work on the subject has been undertaken in North America, Europe and elsewhere. It is only recently, however, that concrete efforts to build such networks have begun. The reasons for this are threefold:

(a) The necessary data bases are only now coming online;

(b) Recent advances in communication and distributed DBMS technology are resolving what had been serious technical problems;

(c) There are growing demands from an increasingly sophisticated user constituency for integrated data sets.

Building on the need for a common information base, but recognizing the need for independent management of the data by individual agencies and government departments, these information networks are being designed to link administrative, environmental and resource management data bases together in order to solve problems which may cross institutional boundaries. In North America, for example, land information networks are now quickly moving from the planning stages to full scale implementation. Several states in Australia also appear to be well under way with network developments, including the Hub network in Queensland and the LOTS system in South Australia. Other jurisdictions are also moving in this direction - for example, the Singapore Land Data Sharing Network. In spite of all the impressive efforts that have been made, most of these networks still represent loosely connected collections of systems. The ready integration of graphical and textual data from different systems is still difficult in a network consisting of hardware and software from perhaps many different vendors. Differing standards for data definitions, data structuring and user interfaces further add to the confusion. However, research in computer science is now under way to address this problem and more focused efforts are being carried out to determine specific networking requirements for spatial information systems. Ezigbalike (1988), for example, explored the system development problems of heterogeneous data base management in a land information network. Webster (1988) presents a framework for examining distributed spatial data bases and discusses current initiatives to solve the problems using existing DBMS technology.

5.5 Standards

Through the mid-1980s, GIS and digital mapping technology involved in most projects were both complex and insular. They operated on sophisticated mini and mainframe computers requiring high-level systems staff to optimize procedures, develop custom enhancements, etc. Production staff were specially trained to operate and maintain the hardware and software involved. Since most such systems were in a data collection mode through these years, many of the data required were either collected or generated in-house. GIS "Standards", when discussed at all, were considered to involve simply the exchange of data files between different systems using interchange formats.

The current digital mapping and GIS environments reflect the exploding number of installations dealing with end-user computing and interconnection. Applications professionals with little or no formal systems background are working on powerful workstations and PC-based systems which may operate on either a stand-alone basis or linked through local or wide area network. In a growing number of cases, these users have had little or nothing to do with the original collection of the data. Levels of user expectation are much higher in this environment. The average microcomputer user is accustomed to working with "forgiving" and easy-to-use software with comprehensive and understandable documentation. In certain cases, these packages will include additional applications "templates" and pre-packaged data sets. Finally, those familiar with office computing have come to expect almost immediate and reliable transfer of data from one application to another. Such users have neither the expertise nor the desire to do extensive programming, nor the concern for data reliability, nor an understanding of the special problems involved in exchanging data between different systems or applications.

Much has been accomplished with respect to spatial data exchange formats. Several formats (e.g. NTF, SDTS, ATKIS and DIGEST) are at advanced stages of development.

However, it must be recognized that spatial information standards must be dealt with in a much broader context than just data exchange. Grosswell et al. (1990) suggest that current computing standards fall into six major classes:

(a) Hardware and physical connection;

(b) Network communication;

(c) Software;

(d) Data format;

(e) Data presentation and user access;

(f) Program design and implementation.

Among some user groups, particularly in the social sciences and business applications, there is also a growing reliance on standard data sets. At the global level, work is already under way on a digital Chart of the World at a scale of 1:1 million, which will be available for public sale after 1992. A number of software vendors have refined and optimized such files and then packaged them with their own systems. Ironically, because of the increasing use of such systems in commercial and mass-market applications, these refined data sets have themselves become de facto standards.

From a spatial information management perspective, then, the current standards efforts can be broken down into three overlapping categories: (a) systems and networks; (b) specifications and formats; and (c) data sets. The categories are shown in the figure.

The central impetus for pursuing GIS standards at present reflects the desire to optimize the use of the hardware/software, people and data resources in an organization. GIS users will benefit from using standards in all three of these areas. Standards, for example, will provide:

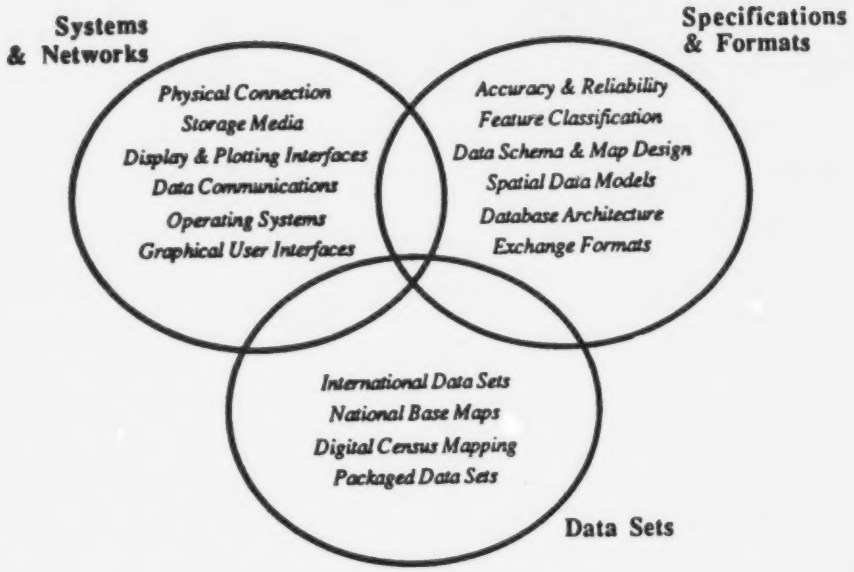
(a) Wider access at all levels within an organization;

(b) Easier exchange of data within and between organizations;

(c) Easier integration of GIS with other systems in an organization;

(d) Transparent data exchange between equipment in a network where multiple systems from different vendors may be in use;

(e) Reduced employee training requirements on initial and subsequent applications;



CATEGORIES OF GIS STANDARDS

(f) Increased emphasis on developing new applications rather than on supporting the proprietary environments of different hardware vendors.

Finally, although standards inevitably change over time, they afford users a more stable production environment and help reduce dependence on the capabilities of individual vendors. Even when listing standards are finally rendered obsolete, new standards usually take older ones into account by allowing for upward compatibility. This should protect the user's investment in the data and makes the integration of GIS more productive over the long term.

But there are also lots of concerns. Waiting for, and adhering to, standards implies some compromise on the part of most users. These compromises may include:

(a) Lower performance: vendors usually optimize their systems using proprietary data structures and techniques. To ensure general compatibility and widespread acceptance, standards usually embody technological compromises that are not the optimal or best-performing solution in many cases;

(b) More limited functionality: in the interests of generality, most standards only encompass a subset of the functions and capabilities available on many systems. As well, there is a tendency to inhibit innovation;

(c) Reduced security: the recent spread of computer viruses was made possible, in part, because more people are now aware of the features (and flaws) of standardized operating systems;

(d) Inconvenience: adoption and adherence to standards can initially increase the effort and expense of completing a project.

Currently, in the software industry, system and network standards are of special importance. GIS users are increasingly realizing that their biggest investment lies not in hardware or software, but rather in the following three areas: (a) data conversion; (b) development and optimization of custom applications; and (c) the learning-curve of both systems staff and end-users with respect to both the software and the data. With this in mind, any GIS standards developed will have to allow for evolving user environment that will outlive listing hardware and software. Looking at the de facto standards already in use, it appears that the best incentive for adopting standards will not be legislation or policy recommendations. Rather, the most effective reasons for an end user to embrace a standard are (a) it exists and is complete across the area of interest, (b) it is simple to access and use and (c) it does the job.

To this end, the following factors can be identified as being practical keys to standards implementation:

(a) If the standard is a data set in itself (e.g., digital base mapping for property mapping), the government organization involved must make the commitment to provide complete and up-to-date coverage as quickly as possible. Incomplete or outdated coverage encourages the adoption of other sources of information which will suit the immediate need;

(b) The standards selected must be easy to access and use. Detailed, understandable documentation must be prepared to promote and support this use;

(c) Where practical, baseline models and examples should be made available to act as default options for the inexperienced and occasional users;

(d) Since organizations may have to deal with counterparts in ind[illegible]l at other levels of government using different standards, any information s[illegible]s adopted must maintain at least a minimum level of compatibility with oth[illegible] standards as well;

(e) Finally, organizations should ensure that technical support for the standard is available from a single, authoritative source in order to minimize confusion during the introduction and testing of standards.

5.6 Management considerations

Increasingly it is recognized that management issues will be of fundamental importance in the development of spatial information systems and especially in co-ordinating the development of distributed information networks. Concerns that need to be addressed will invariably include:

(a) Understanding in depth both current and emerging requirements for spatial information;

(b) Developing appropriate policies for responding to these requirements both in terms of specific projects and in terms of jurisdiction-wide information policies;

(c) Translating these policies into organizational mandates and co-ordinating mechanisms;

(d) Designing funding strategies both for the initial systems development and for its subsequent maintenance;

(e) Developing human resource strategies;

(f) Developing procedures for acquiring the appropriate technology, etc.

This section contains a brief review of the technology assessment and procurement requirement, some economic issues, the human resource challenge and some broader policy concerns.

With respect to procurement, the spatial information manager is faced with a special dilemma. Whereas even a few years ago, there were relatively few technology options available, and the relative strengths and weaknesses of the commercial products were quite distinct, today the situation is much more complicated. In the GIS field, for example, there has been an explosion in the number of systems coming to the marketplace and it has become increasingly difficult to distinguish between their relative merits. As well, there is an

increasing tendency towards building customized solutions (combining software packages from different vendors, often within a networked environment). Software is increasingly independent of hardware and more attention is being given to solutions which can be upgraded over time.

Given these developments, there is a growing trend towards the use of formal technology assessment procedures. These may incorporate: (a) user requirements analyses; (b) definition of required products; (c) evaluation of data management and application requirements; (d) assessment of production rates. A brief summary of some of the more important elements to be considered in acquiring GIS technology is given in Dale (1990). A detailed examination of procedures employed in assessing such technology has been prepared by the U.S. Government (Guptill, 1988). In addition to these assessment procedures, managers must also become increasingly conversant with the policies and procedures involved in the actual procurement process (requests for information, requests for proposals, benchmarking, award of contract, follow-up specifications, etc.). Differences in contract law and administrative procedure make it very difficult to provide general rules in this area although guidelines are available for selected tasks such as benchmarking.

The steps involved in a typical procurement process are described in table 2 (McLaren, 1988). The process will be guided by a user requirement statement (URS), which is used as a reference to create the "request for proposal" (RFP) document and to prepare the benchmark specifications.

The primary purpose of the benchmark is to provide an objective assessment of the suitability and efficiency of a supplier's proposed solution. It should contain tasks that reflect the key functions of the system and should examine such areas as:

(a) Data integration and management;

(b) Data modelling capabilities and the transparency of data structures;

(c) Richness of functionality;

(d) Multi-user applications;

(e) Security;

(f) Richness of query language;

(g) Integration with external data bases;

(h) Ability to customize the system;

(i) Human interface.

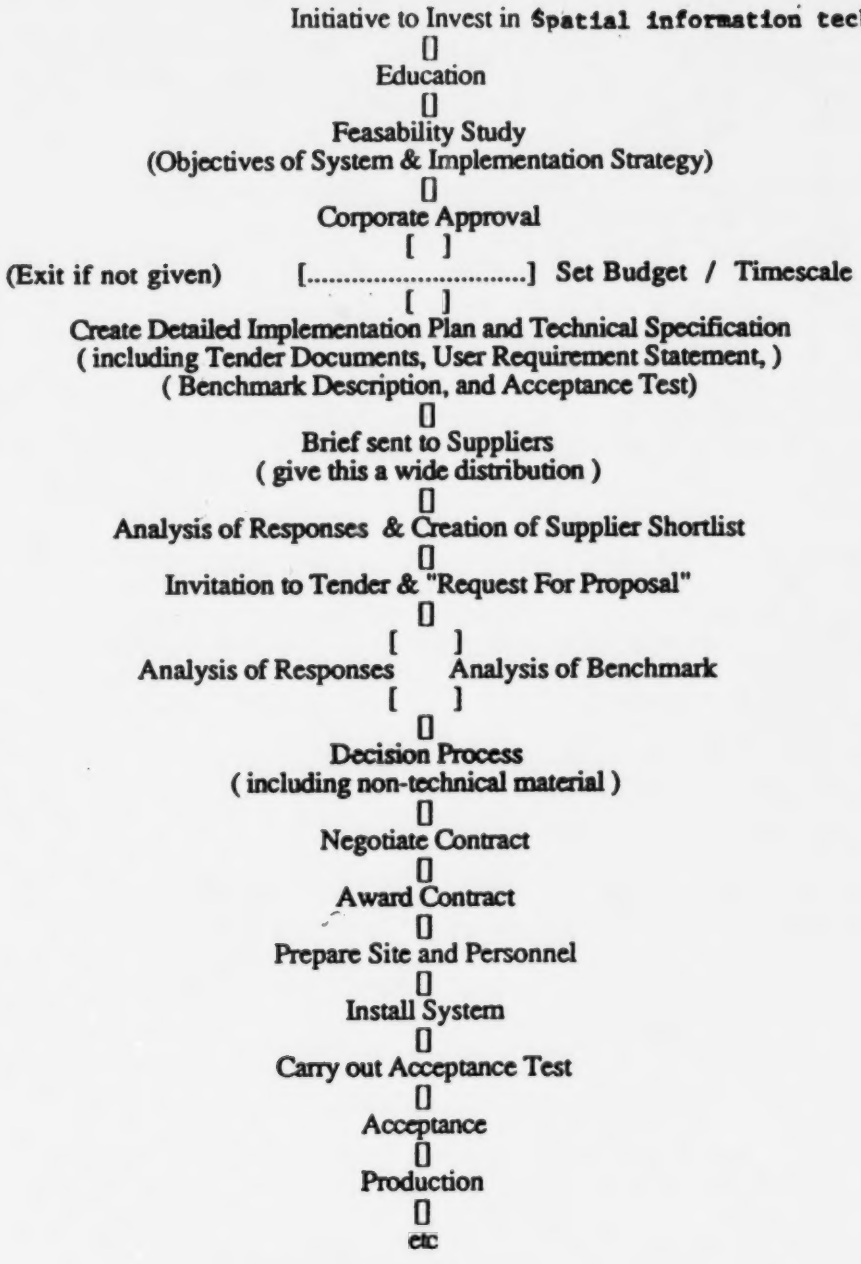

Initiative to Invest in Spatial information technology
Education
Feasability Study
(Objectives of System & Implementation Strategy)
Corporate Approval
(Exit if not given)
Set Budget / Timescale
Create Detailed Implementation Plan and Technical Specification
(including Tender Documents, User Requirement Statement,)
(Benchmark Description, and Acceptance Test)
Brief sent to Suppliers
(give this a wide distribution)
Analysis of Responses & Creation of Supplier Shortlist
Invitation to Tender & "Request For Proposal"
Analysis of Responses
Analysis of Benchmark
Decision Process
(including non-technical material)
Negotiate Contract
Award Contract
Prepare Site and Personnel
Install System
Carry out Acceptance Test
Acceptance
Production
etc

Table 2. Steps involved in a typical procurement process

To fully test the supplier's capability, the benchmark should be organized into three categories:

(a) Tasks to be completed prior to the benchmark, for example the definition of the data model, the preparation of representative test data and the creation of any functions that the buyer has specifically asked for;

(b) Pre-defined tasks to be performed live during the benchmark, for example, the simulation of data bloc update procedures;

(c) Surprise tasks to be performed during the benchmark (McLaren, 1988).

In addition to the benchmarking exercise, various other variables will of course also have to be considered in the procurement process (local maintenance capabilities, compatibility with other hardware and software etc.). Finally the financial considerations will be of fundamental importance (not only in terms of price, but also with respect to local content, costs to upgrade, maintenance costs, etc.)

Turning to other economic issues, documenting the costs associated with building and managing spatial information systems has proved a major challenge. While there are some general "rule-of-thumb" measures (e.g., 70 per cent of the cost of building a system may be associated with capturing the data, maintenance costs on a per annum basis may be in the order of 15-25 per cent of the start-up costs etc.), developing more detailed cost breakdowns has proven a very complex task. This is due in part because:

(a) There are significant variations among and within jurisdictions due to differences in the physical and economic geography, in the nature and complexity of the institutional arrangements, in the structure and content of the listing information structure, etc.;

(b) There is almost always a lack of adequate financial reporting systems such that few proper records of time or expenditure are maintained;

(c) The information costs are rarely separated out from the overall operating costs;

(d) There are often difficulties in reconciling costs shared between different departments and agencies;

(e) The figures available often focus only on the initial production and start-up costs and do not include updating, maintenance, life-cycle, overhead and training costs.

A valuable synthesis of efforts to document such costs was provided in a report by Janis Bernstein for the World Bank (1986). Over the next few years it is anticipated that such more detailed cost documentation may be provided by those agencies which have been required to increase their cost recovery (e.g., the New Zealand Department of Survey and Land Information and the United Kingdom Ordnance Survey).

Another economic issue of growing importance is the development of pricing strategies for land information products. Traditionally, most public goods have been provided at a token price. Government maps and surveys, for example, have been marketed at a price well below their true cost of production. Similarly, cadastral surveying has had direct or hidden subsidies, for example, the true cost of examining surveys undertaken by the private sector has almost never been passed on to the client. Many jurisdictions are now under increasing pressure to move away from this approach, especially as they introduce computerized products and services, and they have had to begin addressing such questions as:

(a) Who should pay for these products and how much;

(b) Whether all front end costs, such as the establishment of geodetic control, should be recovered through fees;

(c) What should be the contribution from general revenues and what from special taxes;

(d) What is the case, if any, for price discrimination between different users and different products?

The New Zealand Department of Survey and Land Information, for example, has had to dramatically change the prices charged for its products and services.

Perhaps the single most important challenge currently facing spatial information managers relates to human resources. While many universities and community colleges have rushed in to provide specialized courses in GIS technology and while any number of vendors and consultants are offering their own short courses, there has not yet evolved a strategic focus to these requirements. However, it is increasingly being recognized that an overall plan covering the broad requirements of the managers, the highly specialized requirements of the systems engineers and technicians, as well as the requirements of the user communities, is urgently needed. Furthermore, it also has to be recognized that as systems develop and evolve, different sets of skill requirements will emerge. These in turn will require increased emphasis on continuing education and the flexible use of staff.

Finally, in terms of the broader policy agenda, there are increasing concerns about who should have access to what data, how concerns about the need for privacy and security should be dealt with, who will be logically responsible for errors or omissions in the data bases, etc. While a discussion of these topics is beyond the scope of this report (for an overview see Dale and McLaughlin, 1988), it is important to stress the concerns of the cartographer in a spatial information environment must go well beyond a narrow technical focus.

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Abbreviations

AIT	Asian Institute of Technology
AM/FM	Automated Mapping/Facilities Management
ARC	Geometrical part of ARC/INFO system; linear component of topological data structure
ATKIS	Amtliches Topographisch-kartogrophisches Informations system (a topographic-cartographic information system in Germany)
AVHRR	Advanced Very High Resolution Radiometer
BLIS	Bangkok Land Information System
CAD/CAM	Computer Aided Design/Computer Aided Manufacture
CAL	Computer-Assisted Learning
CD-ROM	Compact Disk - Read-Only Memory
CODATA	Committee on Data of the International Council of Scientific Unions
DBMS	Data Base Management System
DCR	Digital Cassette Recorder
DEM	Digital Elevation Model
DIGEST	NATO data exchange format
DIME	Duel Independent Map Encoding (US Bureau of the Census)
DLG	Digital Line Graph
DOS	Disk Operating System
DTED	Digital Terrain Elevation Data
DTM	Digital Terrain Model
DXF	Interface of the AUTOCAD software
ELAS	Software package for image analysis
EPSF	An input data format
ERDAS	Earth Resources Data analysis System

FIG	Fédération Internationale de Geomètres
GIBAS	Geographical Information Retrieval and Analysis System
GIS	Geographical Information System
GPS	Global Positioning System
HPGL	Hewlett Packard Graphical Language
ICA	International Cartographic Association
IGES	Intergraph Geographic Encoding System
ISIF	Intergraph Standard Interchange Format
ISPRS	International Society of Photogrammetry and Remote Sensing
ITC	International Training Center for the Earth Sciences (Enschede, Netherlands)
IUSM	International Union for Surveys and Mapping
KFA-1000	Photocamera with focal length = 1000 mm
LAN	Local area Network
LANDSAT	A series of earth-observing satellites serving as platform for multiple sensors
LIS	Land Information System
LOTS	Land Ownership and Tenure System
MIS	Management Information System
MOSS	Map Overlay and Statistical System of US Fisheries and Wildlife agency
NRED	Natural Resources and Energy Division
NTF	National Transfer Format
RFP	Request for Proposal
SDTS	Spatial Data Transfer Standard
SIF	Standard Interchange Format
SPOT	System Probatoire d'Observation de la Terre

TIGER	Topologically Integrated Geographic Encoding and Referencing Scheme of the US Bureau of the Census
UN/DTCD	United Nations Department of Technical Co-operation for Development
UNEP-GRID	United Nations Environment Programme, Global Resource Information Data Base
UNIX	A computer operating system
URS	User Requirement Statement
WAN	Wide Area Network

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